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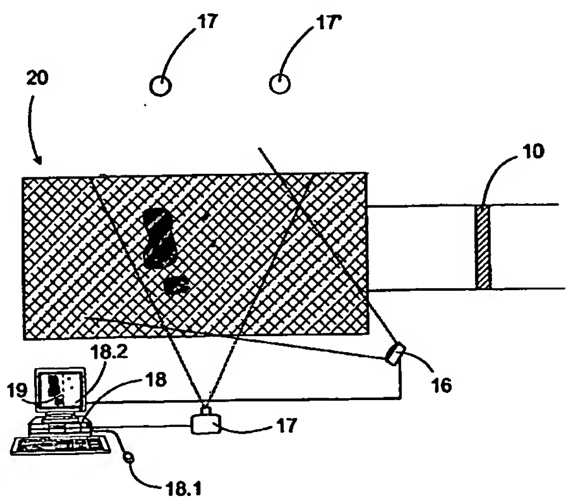
(54) Title: METHOD AND ARRANGEMENT FOR MEASURING A JUMPING DISTANCE



(57) Abstract: The invention relates to a method and arrangement for measuring the jumping distance especially in long jump and triple jump, in which the competitor jumps from a fixed starting line (10) onto the jumping ground (20) that is formed by a clearly defined area of sand etc., and in which the jumping distance is determined by the distance between the edge (14) of the trace left by the jumper's landing that is closest to the starting line and by the starting line (10). At least an essential part of the jumping ground (20) is filmed by a video camera (17) after the jump and from the video picture obtained the position of the said edge (14) on a measuring scale is determined by using a machine vision, the measuring scale having been calibrated in advance in relation to the starting line (10).

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METHOD AND ARRANGEMENT FOR MEASURING A JUMPING DISTANCE

The invention relates to a method and arrangement for measuring the jumping distance especially in long jump and triple jump, in which the competitor jumps from a fixed starting line onto the jumping ground that is formed by a clearly defined area of sand etc., and in which the jumping distance is determined by the distance between the edge of the trace left by the jumper's landing that is closest to the starting line and by the starting line.

Jumping distances have until now mainly been measured by hand. Prism measuring has been used to some extent, in which a system using laser beams has measured the jumping distance. Taking measurements by hand involves a great risk of a measuring error and it is slow. Also prism measuring involves elements of error. A mistake can happen when focussing the measuring prism on the edge of the landing.

The object of this invention is to achieve a new method and arrangement for measuring a jumping distance especially in long jump and triple jump. The characteristic features of the method according to the invention are presented in the accompanying patent claim 1 and the characteristic features of the arrangement intended to implement it are presented in patent claim 10.

In the following, the invention is explained more closely by reference to the accompanying figures that present the arrangement and the act of measuring according to the invention.

Fig. 1 presents the jumping area seen from the side, especially in the direction of the jumping ground, perpendicularly in relation to the jumping direction.

Fig. 2 presents from above the traces left by the landing.

Fig. 3 presents the filming area of the camera.

Fig. 4 presents the arrangement according to the invention as a whole.

The measuring arrangement for jumps in the longitudinal direction, based on a machine vision, consists of the following parts (fig. 4):

1. 1 - 3 video cameras 17. The cameras are cameras intended to be used for measuring within the industry, the mechanical structure of which is strong and the attachments of which make it possible for the direction of the camera to stay unchanged despite the effects the wind or small knocks. Furthermore, in this case the synchronising of the camera at the time of measuring has been effected by so-called asynchronous resetting, which enables the reliable and correctly timed reading of the picture data of the camera into the computer.

2. A PC computer 18, inside which there is a card that performs an A/D transformation on the picture that comes in from the video camera. With the help of this card, the video picture is transformed into numerical form. The computer naturally includes a screen 18.2 for the monitoring of the pictures and a pointing device, for example a mouse 18.1, to enable graphic pointing directly in the picture.

3. A flash device 16, which has been fixed so that its light comes, when directed, from close to the direction of jumping board 10. The effect of the flash is 1200 joules, whereby during a very short time of exposure (1/10000 s) its light intensity on the jumping ground clearly exceeds the intensity of sunlight. Hereby any changes in cloudiness or other changing circumstances do not cause changes at the time of measuring. The opening of the camera and the time of exposure have been set so that a picture taken without the flash is almost black in full sunlight.

The functional principle of the measuring device is as follows. Immediately before the performance of each competitor, the apparatus takes a picture of the jumping ground 20 with flash lighting and stores the picture into the memory of the computer 18. Another picture of the jumping ground is taken after the jumping performance. By comparing these two pictures, the space closest to the jumping board 10 in which changes have taken place after the jump is determined. The angle of sight of the camera 17 has been calibrated so that, on the basis of the coordinates of this point, the corresponding jumping distance can be disclosed. The rough video picture that is obtained is corrected for further handling at least in the longitudinal direction so that targets that are on the same transverse line are, in fact, filmed onto the same vertical line (cursor 19) on the screen. Jumping board 10 includes some more precisely defined jumping line, which forms a stable measuring point when measuring jumps.

Despite of the use of a picture of comparison, the jumping area should be evened out mechanically. US patent publication 5,779,390 presents one levelling machine for this purpose.

Certain changes have been made to the main principles that enable the reliable measuring in different circumstances:

1. Only such spaces that are darker after the jump than the prior picture (of comparison) are taken into account from the differences in the pictures taken before and after the jump. This is a consequence of the reasons illustrated in figure 1. The lighting direction of the flash is such that its beams of light come from the direction of the board 10, from a lamp that is approximately at the height of 70 centimetres. The camera instead looks onto the jumping ground 13 high up from the side. Hereby the hollow 11 made by each jumper casts a shadow in the manner presented in the figure, and the length of the jump can be measured from the edge 12 of that shadow that is closest to

the board 10. In certain cases, however, the jumper sits his jump in such a way that he presses the sand backwards into a gentle heap. Here the edge of the heap that points to the board 10, well lit by the flash, is shown as an area lighter to the picture of comparison. However, this is not taken into account in the jumping distance, but only the area that is cast into the shade in the figure, which has, for instance, an impression left by the buttocks.

Figure 1 is in the direction of the surface of the jumping ground, perpendicularly in relation to the jumping direction.

2. Only such places are taken into account in the measuring in which the uniform area that is left in the shade is greater than the limiting value of the surface area that is set by the user. The reason for this is that e.g. the wind can blow small grains of sand at the jumping area and these can leave a small shadow, 14, figure 2. Similarly, in the landing of the jump 15 small grains of sand can spatter backwards. The boarder value may be fixed for instance so that only uniform areas of more than 200 mm^2 are taken into account. However, the value has to be small enough so that e.g. a trace left by a hand 9 is included. This has been illustrated in figure 2.

Figure 2 is from the top, the black areas are seen as shadow areas in the flash lighting.

3. Only such places are included in the measuring in which the shadow is dark enough. An attempt is thereby made to avoid circumstances in which e.g. the jumper's hair has scratched the surface of the sand and the jump picture shows a shadow that is not very dark. On the other hand, clear hollows in which the darkness of the shadow exceeds the fixed limiting value are included.

4. Despite of all the stages checked, unexpected circumstances can always occur in the midst of the competition, e.g. an extra particle can fly from the stand onto the jumping ground, which creates a large shadow in the picture. In order to correct such circumstances, a characteristic is added to the next version of the programme in order to allow the user himself to set the place of a virtual "measuring stick". The decision on this is taken as follows. The monitor of the computer shows a picture taken after the jump, which shows the place of landing. Onto this the computer has drawn the borders of the areas left in the shade on the basis of the difference between the two above mentioned pictures and the place of the point of measuring that is automatically determined in the above mentioned way. If the user now considers that the computer has drawn the point of measuring in the correct place, he will accept the result. In case he, on the other hand, considers that there is something extra in the picture closer to the board, he can with the help of the mouse move the cursor on the picture onto the spot that he considers to be correct. The cursor is drawn in such a way that the distortion of the perspective in the view of the camera is corrected, i.e. that there is no risk that he will chose a place that would not be closest to the board due to the perspective. Based on the place of the cursor, the computer will calculate the corrected result.

The cursor choice can also be taken from a picture taken without the flash and wholly independently without form recognition.

There are three types of factors that influence the accuracy of the measurements:

- the accuracy of the measuring method itself
- the accuracy by which the measuring apparatus is calibrated in relation to the coordinates of the place of measuring
- the way the "correct" point of measuring is chosen

In the following, the two first mentioned elements of error are first examined.

1. The resolution of the camera, i.e. the number of separate picture points. In the calibrating situation, the camera is directed in such a way that its horizontal direction becomes equal to the direction of the jump so that the horizontal resolution of the camera is of essential importance. In the chosen camera, this resolution is 768 picture points. In an ideal camera, the maximum inaccuracy would be ±½ picture points, but other factors exist in addition to this.

2. Lens errors

In comparison to an ideal lens, the objectives used in practice cause considerable geometric distortions in the picture. These include inter alia the radial and tangential distortion and the displacement of the optical central point in relation to the central point of the picture cell. Each camera-objective combination has to be calibrated separately in order to eliminate these errors. A calibrating programme with the help of which the standard error can be reduced to ±0,2 picture points on the whole area filmed is profitably used.

3. The distortion of the perspective and the calibrating of the place of the camera onto the place of measuring.

In addition to the errors mentioned above, the camera must have its own place in relation to the board and the level of the jumping ground at each place of measuring, in order for the measurements to be accurate. The camera has been fixed so as to watch the jumping ground from an oblique angle so that there is a great perspective distortion in the view the size of which depends on the position of the camera. The position of the camera and its place in relation to the board are calibrated separately in each place of measuring. Special calibrating

markings are here used, which are set onto places of the area of sight the positions of which are fixed by hand with the help of a steel measure (both the distance from the board and the perpendicularity to the board with a cross-measure or a square). The above mentioned markings are filmed with the camera and with the help of these the computer programme will calculate the place of the camera and the turning angle in relation to the jumping ground and will set the distance of the picture field to the board. Taking advantage of the measurements, a perspective correction is made to each measuring picture on the basis of known matrix equations. The programme also notifies the user of the maximum mistake that can have been made whilst using the calibrating markings. The user will only accept the calibration when the calibrating error is less than 0,2 millimetres. A partial pixel technique can be used in the calibration process, i.e. the error is much less that one picture point (pixel).

4. The drawing ability of the camera-objective combination. The drawing ability must be adequate in such a way that the camera is able to separate details as small as of the size of a pixel. The drawing ability at the point of 50% of MTF is notified to the chosen objective as at least 100 pairs of lines/mm. Such a camera is chosen that the size of its picture points in the horizontal direction is 0,0116 mm, whereby the drawing ability sufficient for it would be as weak as 50 pairs of lines/mm.

5. The size of the filmed area
Due to the perspective distortion, the filmed area is of the form of a parallelogram, figure 3. Thereby the area covered by one picture point is at its largest at the outmost edge of the filmed area. In the new version of the measuring system, the filmed area is chosen in such a way that it is 2,8 m at the outmost edge and 1,76 m (the width of the jumping ground is 3 m) at the nearest edge for one camera. The area is thus as presented in the following figure. In the typical situation, a

greater area need be covered in the measuring of a jump, whereby two cameras 17 and 17' are used (the sight area of the possible other camera indicated with a broken line).

Due to the form of the filmed area, the accuracy of the measurements is different closer to the camera than farther away from it. Farthest away one pixel covers 3,65 mm, i.e. the measuring accuracy with an ideal system would be ±1,83 mm and correspondingly closest to the camera ±1,15.

Having regard to the size of the filmed area and the listed sources of error it is possible to calculate the combined inaccuracy at the longer distance:
±1,83 (theoretical resolution) + 0,73 (lens errors) + 0,2 (errors in the calibration of the position) mm ≡ 2,8 mm and correspondingly at a close distance: ±(1,15+0,46+0,2)mm ≡ ±1,9 mm.

Correspondingly at the centre of the filmed area, onto which most of the jumps are directed, it follows that the inaccuracy is less than ±2,8 mm.

In addition to the above mentioned errors, human mistakes must be taken into account in practice, e.g. the fact that the edge of the jumping board is used up to a different degree in different places in the calibrating situation, so that mistakes may happen in the setting of the calibration markings. This is, however, exactly the same situation as when using any other method.

However, it must be noted that when using the ordinary methods, in which a measuring stick or prism is set onto its place by hand, the possibility of a human mistake is much bigger and the error is different in relation to each jump. A measuring prism can have a spirit level bubble, with the help of which most people do get it upright, but in the setting the error is often

made that whilst pushing the end of the spike into the right spot it is pushed in an oblique angle, whereby the error can easily be more than 5 mm when the prism is eventually set upright. A considerably greater possibility of an error exists in the situation where the jumper has landed on the sand with his feet. The person setting the measuring stick in its position must now evaluate which foot has been closer to the board. If the feet have been wide apart and the difference is small, it is very possible that the foot farther away is chosen by mistake, whereby the error can be more than 10 mm. Verificatory measurements are not often made. Another mistake often happens when the sand is dry: the measurer looks for the edge of a steep hollow that is clearest to his mind, although the jumper would have made a more gentle hollow closer to the board. In a mechanical measuring the difference will be noted. The greatest advantage of mechanical measuring is that the criteria for measuring are the same for all jumpers.

The system seen from the top is shown in figure 4. The board 10, the flash light 16, the camera 17 fixed onto the jumping area and the computer 18 (PC) are presented in the figure. The computer 18 controls the camera 17 and the flash light 16. The computer 18 includes a pointing device, here a mouse 18.1 in order to move the cursor 19 visible on the screen.

Claims

1. A method for measuring the jumping distance especially in long jump and triple jump, in which the competitor jumps from a fixed starting line (10) onto the jumping ground (20) that is formed by a clearly defined area of sand etc., and in which the jumping distance is determined by the distance between the edge (14) of the trace left by the jumper's landing that is closest to the starting line and by the starting line (10), characterised in that at least an essential part of the jumping ground (20) is filmed by a video camera (17) after the jump and from the video picture that has been obtained, the position of the said edge (14) on a measuring scale is fixed by using a machine vision, the measuring scale having been calibrated in advance in relation to the starting line (10).

2. Method according to patent claim 1, characterised in that the video filming is carried out from the side of the jumping ground (20), whereby the rough video picture is distorted as to its geometry, which is corrected for further handling at least in the longitudinal direction.

3. Method according to patent claim 1 or 2, characterised in that the video picture is shown to the operator and a cursor (19) is added to it to be used by the operator, the position of which on the screen is calibrated to correspond to the measure of length on the filmed area at least in the longitudinal direction and which the operator takes to the edge that he has chosen and accepts the choice whereby the accepted place of the cursor indicates the measured distance.

4. Method according to patent claim 3, characterised in that the cursor (19) is a transverse line.

5. Method according to patent claim 1 or 2, characterised in that a digital video picture is produced, encompassing a group

of pixels in matrix form, the intensity values of which are classed at least into two classes, one class representing the shadow areas, out of which the said edge is sought with the help of form recognition.

6. Method according to patent claim 5, characterised in that a minimum requirement is set on the size of the shadow area, whereby smaller areas are removed from the video picture before the determining of the jumping distance.

7. Method according to one of the above patent claims 1 - 6, characterised in that the video filming is done with flash lighting (16), the light intensity given by which on the jumping ground (20) clearly surpasses the intensity of sunlight.

8. Method according to one of the above patent claims 1 - 7, characterised in that a comparison video picture is taken before the jump, to which the video picture taken after the jump is compared and only the changed parts of the video picture are taken to further handling.

9. Method according to one of the above patent claims 1 - 8, characterised in that the jumping ground (20) is evened mechanically before the jump.

10. Arrangement for measuring the jumping distance especially in long jump and triple jump, in which the competitor jumps from a fixed starting line (10) onto the jumping ground (20) that is formed by a clearly defined area of sand etc., and in which the jumping distance is determined by the distance between the edge (14) of the trace left by the jumper's landing that is closest to the starting line and by the starting line (10), characterised in that the arrangement encompasses a camera (17) that films the jumping place, a flash light (16) and a computer (18) onto which these are connected and in which

the computer (18) is set to control the camera (17) and the flash light (16) and, being directed by a user, to determine the jumping distance from the picture given by the camera (17).

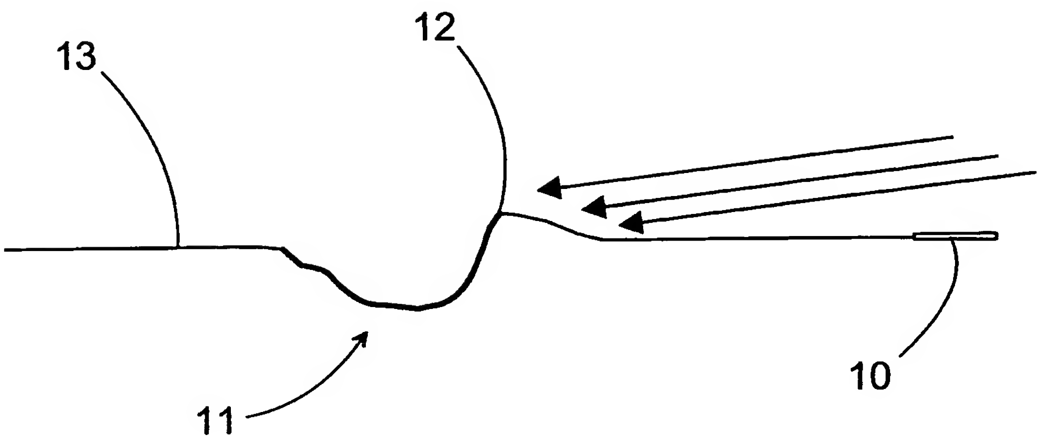

Fig. 1

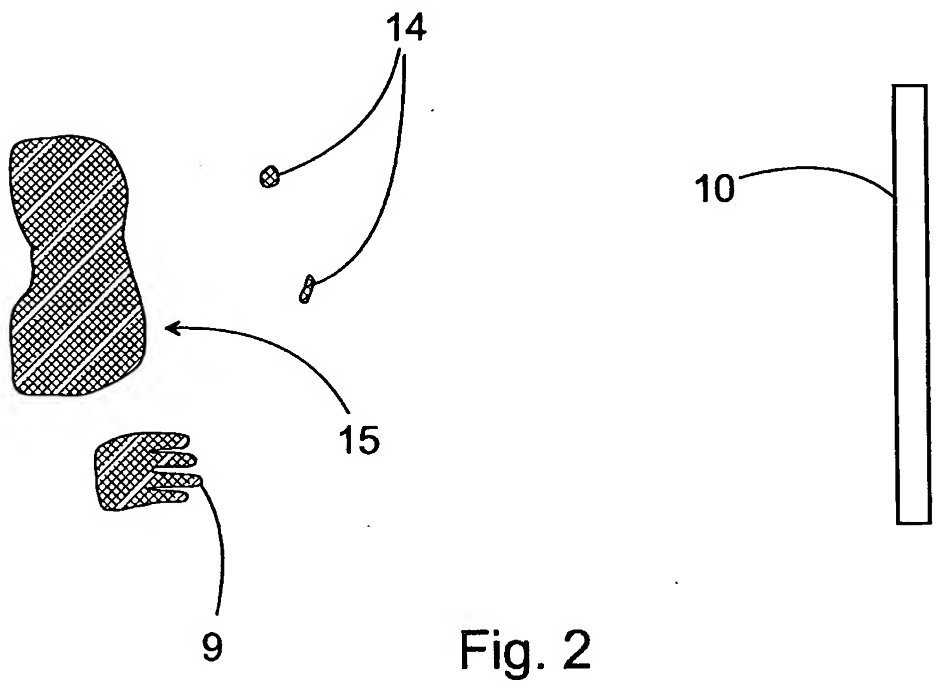

Fig. 2

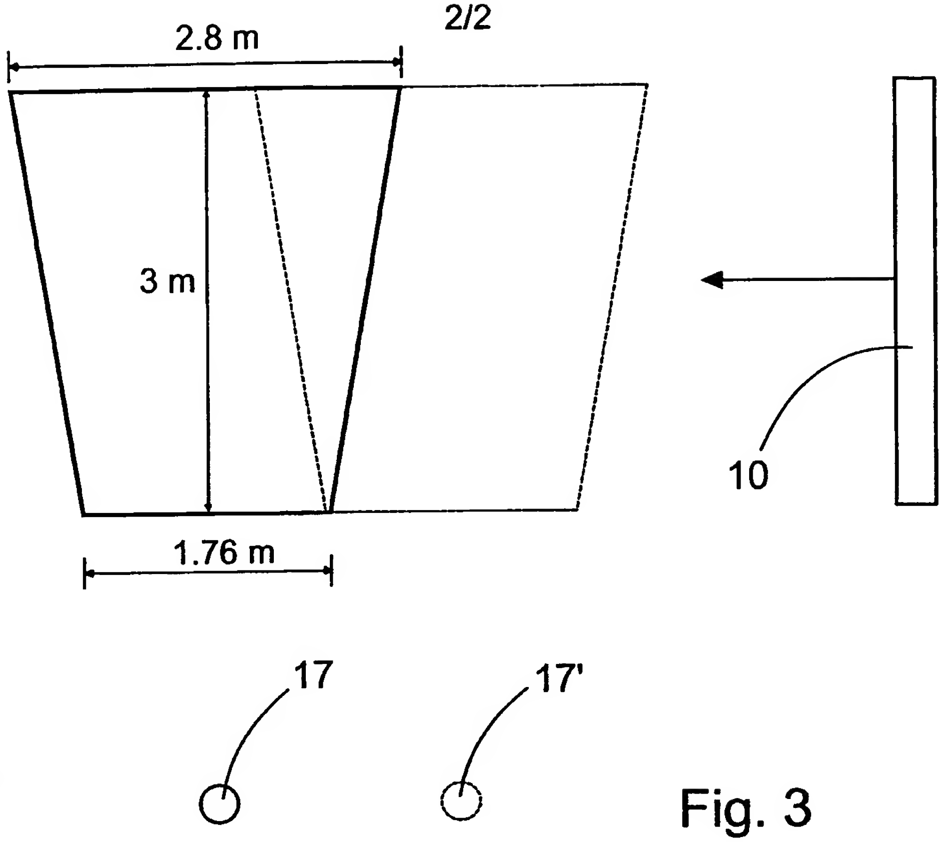

Fig. 3

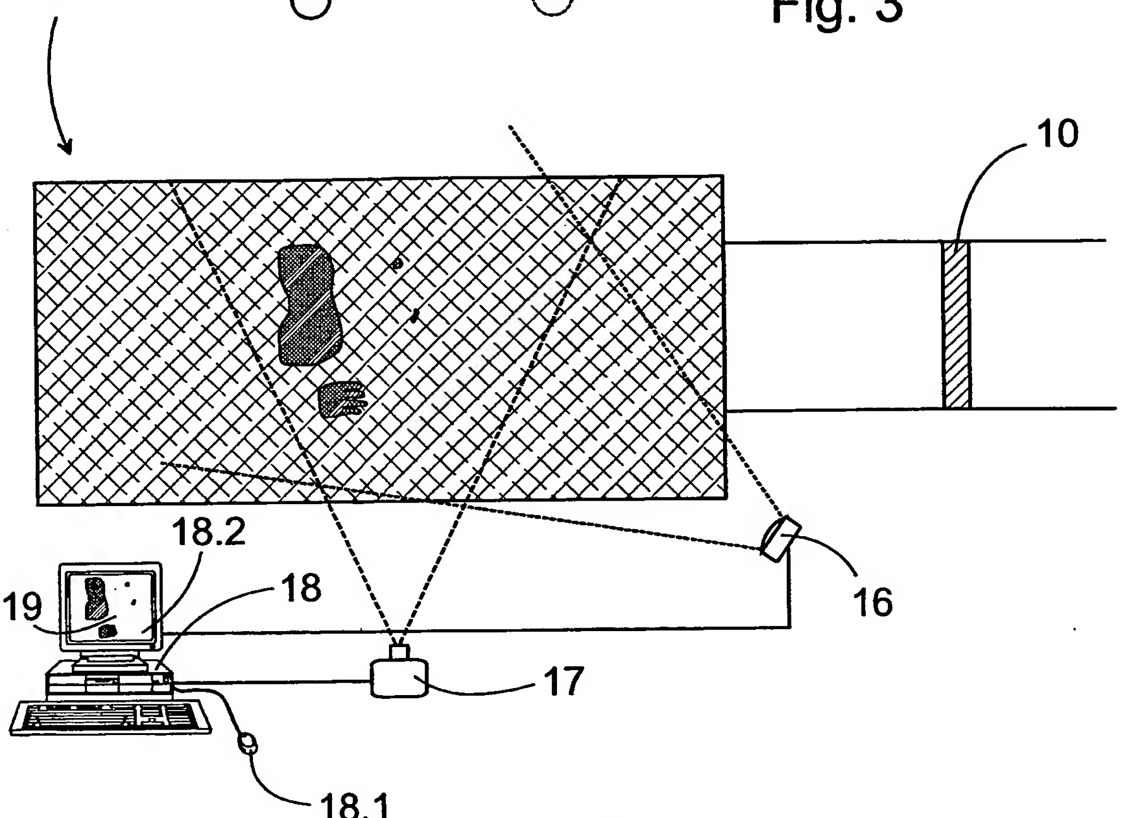

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00474

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01B 11/02, G06T 7/60, A63B 5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01B, G06T, A63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 4141397 A1 (IMHOF,AUGUSTIN), 17 June 1993 (17.06.93), figure 1 --	1-10
A	DE 4030507 A1 (STICHHAN, ALBERT), 2 April 1992 (02.04.92), figure 1b --	1-10
A	GB 1400225 A (WILLAMOS BERENDEZES ES KESZULEK MUVEK), 16 July 1975 (16.07.75), figure 3 -- --------	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 Sept 2000	20-09-2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Sture Elnäs/MN Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

28/06/00

International application No.
PCT/FI 00/00474

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
DE	4141397	A1	17/06/93	NONE			
DE	4030507	A1	02/04/92	NONE			
GB	1400225	A	16/07/75	CA	970556	A	08/07/75
				CS	163291	B	29/08/75
				DD	101559	A	12/11/73
				DE	2258209	A	14/06/73
				FR	2164256	A	27/07/73
				HU	164351	B	28/01/74
				IT	975932	B	10/08/74